

# **Marine Fish and Invertebrate Atlas: Summarizing Geographic Distribution and Population Indices in the Scotian Shelf and Bay of Fundy (1970-2020)**

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MARINE FISH AND INVERTEBRATE ATLAS: SUMMARIZING GEOGRAPHIC DISTRIBUTION  
AND POPULATION INDICES IN THE SCOTIAN SHELF AND BAY OF FUNDY (1970-2020)

by

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## **ABSTRACT**

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The summer groundfish research vessel survey on the Scotian Shelf and in the Bay of Fundy started in 1970 and was designed to measure the distribution and abundance of major commercial fish species. Over time, additional information on non-commercial species was collected, and allowed considerable insight into ecosystem function and structure, as documented in many primary publications whose analyses used the survey data. The same groundfish survey database has also been used to produce species status reports, atlases of species distribution and remains an essential source of information for stock assessments in the Maritimes Region of Fisheries and Oceans Canada. This report builds on previous work and former atlases by updating a comprehensive suite of indices to assess population status and environmental preferences of 104 species. For each species, trends in geographic distribution and biomass or abundance were plotted. The spatial extent of distribution was plotted over time to gauge how the area occupied has changed. The relationship between abundance or biomass and spatial extent reflected whether the species distribution expands when abundance or biomass increases. Length frequencies over time depicted any changes in mean size. The plots of condition over time revealed whether individual fish are fatter or thinner than their long term mean. Depth, temperature and salinity preferences were estimated to gauge the range of suitable environmental parameters for each species. Finally, for each stratum, the slope describing how local density varies with regional abundance was estimated.

## RÉSUMÉ

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## 1 Introduction

The summer (July-August) groundfish research vessel survey on the Scotian Shelf and in the Bay of Fundy was started in 1970 by Fisheries and Oceans Canada Maritimes Region. The survey was originally designed to measure the distribution and abundance of major commercial fish species. Over time, information on non-commercial species was also collected. The groundfish survey database storing the information collected during the annual survey provides the main source of fisheries-independent information for marine species in the region. This information is routinely used to support stock assessments, to produce species status reports and has been previously used to publish atlases of species distribution.

The current document is an update of an earlier report (Ricard and Shackell 2013) that built on former atlases by updating a comprehensive suite of derived indices for 104 species to assess population status and environmental preferences. The information collected during the survey is stored in a relational database management system archived at Fisheries and Oceans Canada Maritimes Region which contains detailed information about the sampling locations and the associated catch. Tow-level survey data is also publicly available from the Ocean Biogeographic Information System (DFO 2016) and (FGP link TBA). The present atlas follows on the work done by Fisheries and Oceans colleagues from the northern Gulf of St. Lawrence (Bourdages and Ouellet 2012), southern Gulf of St. Lawrence (Benoît et al. 2003) and on earlier work in the Scotian Shelf (Simon and Comeau 1994; Horsman and Shackell 2009).

To facilitate updates and foster collaboration on the analyses of the survey data, the computer code necessary to extract the data, to perform the analyses presented herein, and to reproduce and update the current document is made available in a git repository (Ricard and Gomez 2021).

The survey area covers three major Northwest Atlantic Fisheries Organization (NAFO) zones that divide the shelf into the colder east 4V and 4W (strata 440-466) and warmer west 4X (strata 470-495). Temporal trends are plotted by NAFO regions for several species. For each species, trends in geographic distribution and biomass or abundance are plotted. Some caution is required in interpreting the results obtained for several taxa due to low sample size as explained later in the text. The spatial extent of distribution is plotted over time to gauge how the area occupied has changed. The relationship between biomass and spatial extent reflects whether the species distribution expands when biomass increases. For each strata, the slope describing how local density varies with regional abundance was estimated (Myers and Stokes 1989). These slopes were then plotted against a habitat suitability index to identify important strata for each species. Then, length frequencies over time depicted any changes in mean size. The plots of condition over time revealed whether individual fish are fatter or thinner than their long term mean. Finally, depth, temperature and salinity preferences were estimated to gauge the range of environmental parameters (Perry and Smith 1994). A full ecological interpretation of trends is beyond the scope of this report. Other documents stemming from peer-reviewed scientific processes under the auspices of the [Canadian Science Advisory Secretariat](#) (CSAS) provide further descriptions of spatio-temporal trends in different indicators and put the information collected during the summer groundfish research vessel survey in a more focused context (see for example Clark and Emberley (2011)).



## 2 Methods

### 2.1 Survey Description

The survey is conducted annually in July-August and covers the Scotian Shelf and the Bay of Fundy (Figure 1). It normally involves two separate two-week trips on board an offshore fisheries vessel from the Canadian Coast Guard.

A number of changes in fishing gear type and vessels used occurred since the onset of sampling activities (Clark and Emberley 2011).

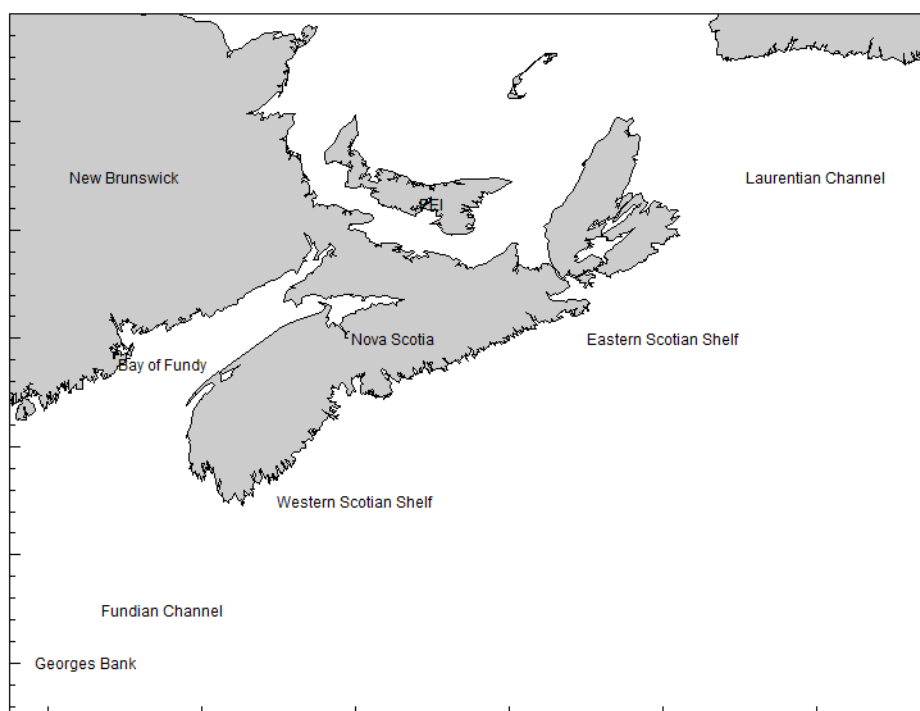


Figure 1. Map of the Scotian Shelf and Bay of Fundy.

## 2.2 Sampling Design

The summer survey covers divisions 4V, 4W and 4X of the Northwest Atlantic Fisheries Organization (NAFO) which includes the Scotian Shelf and the Bay of Fundy. The eastern limit of the survey is the Laurentian Channel and the western limit is the Fundian Channel (Figure 1).

The survey follows a stratified random design (Doubleday and Rivard 1981; Lohr 1999) (Figure 2). The number of tows conducted in each stratum is approximately proportional to its surface area.

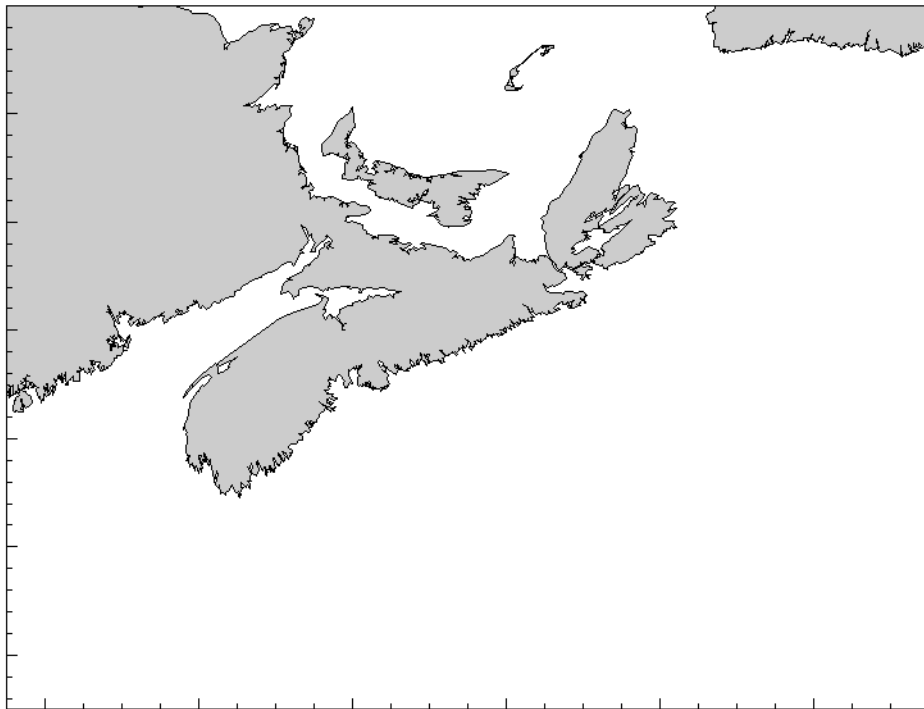


Figure 2. Map of the Summer survey strata.

The basic sampling unit of the survey is a 30-minute fishing tow conducted at a speed of 3.5 knots. This yields a distance towed of 1.75 nautical miles.

After each tow the catch is sorted by species and weighed. Each fish caught is then measured, and further sampling of individual fish weight, maturity status and age are performed for different length classes. When catches exceed 300 individuals, a random sub-sample is used to obtain the length and weight measurements.

The location of representative tows appears in Figure 3.

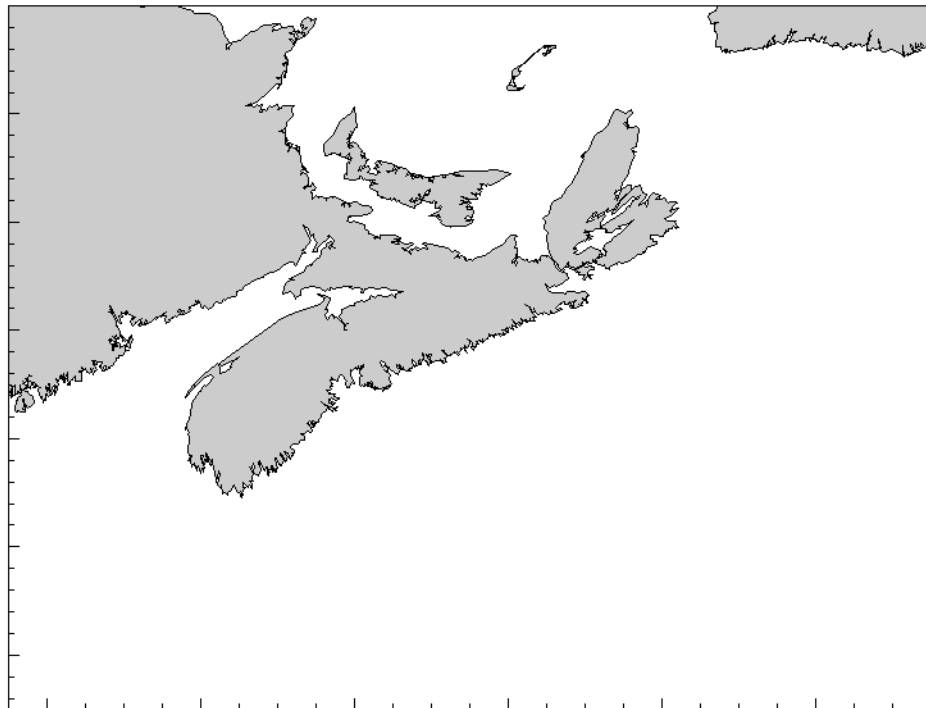


Figure 3. Map of the Summer survey tows.

## 2.3 Taxonomic Levels

Fish species caught during the surveys are identified by trained scientific personnel and their scientific name is determined. An internal species code used in the relational database is reported for each species (Losier and Waite 1989).

By its nature as a bottom trawl, the fishing gear used in the survey catches certain species better than others. To ensure that meaningful ecological information can be extracted from catch samples, we report the catch records for the subset of species that are caught reliably by the gear. To appear in this atlas, a species must have had a minimum of 10 observations over the duration of the survey activities. While both catch abundance and weight are recorded, the weight of species that appear at low abundances is often recorded as zero in the earlier parts of the survey when scales of appropriate precision were not available.

We divided the species caught into five categories based on 1) their taxonomic classification, 2) the number of recorded observations, and 3) their period of valid identification (Table 1). Category "LF", for "long frequent", was assigned to species that have more than 1000 records since 1970 and have been consistently identified since the onset of the survey. Category "LI", for "long intermediate", was assigned to species that had between 1000 and 200 catch records. Rare and elusive species (those with less than 200 catch records over the duration of the survey) are also reported but to a lower level of analytical details (Category "LR", for "long rare"). Category "SF", for "short frequent", was assigned to invertebrate species that were consistently sampled only since 1999 (Tremblay M. J. 2007). And category "SR", for "short rare" for invertebrate species consistently sampled only since 1999 and with less than 200 catch records. The list of taxa covered in this document is presented in phylogenetic order (Nelson J. S. et al. 2004) in Table 2. To ensure concordance with authoritative taxonomic information, the AphiaID from the World Register of Marine Species is also provided in Table 2 (Appeltans et al. 2012).

Category	Name	Description
L	long	consistently identified since the onset of the survey in 1970
LF	long frequent	species that have more than 1000 catch records
LI	long intermediate	species that had between 1000 and 200 catch records
LR	long rare	species with less than 200 catch records
S	short	invertebrate species that were consistently sampled only since 1999
SF	short frequent	species with more than 200 catch records
SR	short rare	species with less than 200 catch records

Table 1. Taxonomic levels

Table 2. List of species included in the Atlas. The species reported here are listed in phylogenetic order as per Page L. M. et al. (2013). For each taxonomic order and class, each species is listed in the table, its taxonomic family and scientific name is provided, along with its French and English common names, the species code used in the survey database, its AphiaID and a link to the World Registry of Marine Species, its number of catch records in the survey database and its classification category as defined in section 2.3.

Family	Scientific name	English name	French name	Species code	AphiaID	Num. records	Category
<b>Myxini</b>							
<i>Myxiniiformes</i>							
Myxinidae	<i>Myxine glutinosa</i>	Atlantic hagfish	Myxine du nord	241	<a href="#">101170</a>	804	I
<b>Petromyzonti</b>							
<i>Petromyzontiiformes</i>							
Petromyzontidae	<i>Petromyzon marinus</i>	Sea lamprey	Lamproie marine	240	<a href="#">101174</a>	16	LR
<b>Actinopterygii</b>							
<i>Gadiiformes</i>							
Gadidae	<i>Gadus morhua</i>	Atlantic cod	Morue franche	10	<a href="#">126436</a>	5451	L
	<i>Melanogrammus aeglefinus</i>	Haddock	Aiglefin	11	<a href="#">126437</a>	5827	L
	<i>Urophycis tenuis</i>	White hake	Merluche blanche	12	<a href="#">126504</a>	3524	L
Phycidae	<i>Urophycis chuss</i>	Red hake	Merluche écureuil	13	<a href="#">126503</a>	2195	L
Merlucciidae	<i>Merluccius bilinearis</i>	Silver hake	Merlu argenté	14	<a href="#">158962</a>	4936	L
	<i>Brosme brosme</i>	Cusk	Brosme	15	<a href="#">126447</a>	688	I
	<i>Pollachius virens</i>	Pollock	Goberge	16	<a href="#">126441</a>	2787	L
Gadidae	<i>Microgadus tomcod</i>	Atlantic tomcod	Poulamon atlantique	17	<a href="#">158928</a>	44	LR
Merlucciidae	<i>Merluccius albidus</i>	Offshore silver hake	Merlu argenté du large	19	<a href="#">158748</a>	161	LR
<i>Scorpaeniformes</i>							
Sebastidae	<i>Sebastes</i>	Atlantic redfishes	Sébastes de l'Atlantique	23	<a href="#">126175</a>	4152	L
<i>Pleuronectiformes</i>							
Pleuronectidae	<i>Hippoglossus hippoglossus</i>	Atlantic halibut	Flétan de l'Atlantique	30	<a href="#">127138</a>	1634	L

Family	Scientific name	English name	French name	Species code	AphiaID	Num. records	Category
	<i>Reinhardtius hippoglossoides</i>	Greenland halibut	Flétan noir	31	<a href="#">127144</a>	736	I
	<i>Hippoglossoides platessoides</i>	American plaice	Plie canadienne	40	<a href="#">127137</a>	6023	L
	<i>Glyptocephalus cynoglossus</i>	Witch flounder	Plie grise	41	<a href="#">127136</a>	4301	L
	<i>Limanda ferruginea</i>	Yellowtail flounder	Limande à queue jaune	42	<a href="#">158879</a>	3233	L
	<i>Pseudopleuronectes americanus</i>	Winter flounder	Limande-plie rouge	43	<a href="#">158885</a>	1632	L
Paralichthyidae	<i>Citharichthys arcifrons</i>	Gulf Stream flounder	Plie du Gulf Stream	44	<a href="#">158791</a>	382	I
<i>Perciformes</i>							
Anarhichadidae	<i>Anarhichas lupus</i>	Atlantic wolffish	Loup atlantique	50	<a href="#">126758</a>	1572	L
	<i>Anarhichas minor</i>	Spotted wolffish	Loup tacheté	51	<a href="#">126759</a>	20	LR
	<i>Anarhichas denticulatus</i>	Northern wolffish	Loup à tête large	52	<a href="#">126757</a>	17	LR
<i>Clupeiformes</i>							
Clupeidae	<i>Clupea harengus</i>	Atlantic herring	Hareng de l'Atlantique	60	<a href="#">126417</a>	3487	L
	<i>Alosa sapidissima</i>	American shad	Alose savoureuse	61	<a href="#">158670</a>	468	I
	<i>Alosa pseudoharengus</i>	Alewife	Gaspereau	62	<a href="#">158669</a>	977	I
<i>Osmeriformes</i>							
Osmeridae	<i>Osmerus mordax</i>	Rainbow smelt	Éperlan arc-en-ciel	63	<a href="#">126737</a>	59	LR
	<i>Mallotus villosus</i>	Capelin	Capelan	64	<a href="#">126735</a>	540	I
Perciformes	<i>Scomber scombrus</i>	Atlantic mackerel	Maquereau commun	70	<a href="#">127023</a>	696	I
<i>Gadiformes</i>							

Family	Scientific name	English name	French name	Species code	AphiaID	Num. records	Category
Phycidae	<i>Phycis chesteri</i>	Longfin hake	Merluche à longues nageoires	112	<a href="#">158988</a>	784	I
Lotidae	<i>Enchelyopus cimbrius</i>	Fourbeard rockling	Motelle à quatre barbillons	114	<a href="#">126450</a>	693	I
<i>Perciformes</i>							
Labridae	<i>Tautoglabrus adspersus</i>	Cunner	Tanche-tautogue	122	<a href="#">159785</a>	82	LR
<i>Scorpaeniformes</i>							
Sebastidae	<i>Helicolenus dactylopterus</i>	Blackbelly rosefish	Sébaste chèvre	123	<a href="#">127251</a>	610	I
<i>Pleuronectiformes</i>							
Paralichthyidae	<i>Hippoglossina oblonga</i>	Fourspot flounder	Cardeau à quatre ocelles	142	<a href="#">158833</a>	76	LR
Scophthalmidae	<i>Scophthalmus aquosus</i>	Windowpane flounder	Turbot de sable	143	<a href="#">158907</a>	115	LR
<i>Aulopiformes</i>							
Chlorophthalmidae	<i>Parasudis truculenta</i>	Longnose greeneye	Oeil-vert à long nez	149	<a href="#">158868</a>	45	LR
<i>Myctophiformes</i>							
Myctophidae	<i>Myctophidae</i>	Lanternfishes	Poissons-lanternes	150	<a href="#">125498</a>	160	LR
<i>Aulopiformes</i>							
Chlorophthalmidae	<i>Chlorophthalmus agassizi</i>	Shortnose greeneye	Éperlan du large	156	<a href="#">126336</a>	78	LR
<i>Stomiiformes</i>							
Sternoptychidae	<i>Mauroliscus muelleri</i>	Silvery lightfish	Brossé améthyste	158	<a href="#">127312</a>	52	LR
Stomiidae	<i>Stomias boa</i>	Boa dragonfish	Dragon-boa	159	<a href="#">127374</a>	20	LR
<i>Argentiniformes</i>							
Argentinidae	<i>Argentina silus</i>	Greater argentine	Grande argentine	160	<a href="#">126715</a>	963	I
<i>Scorpaeniformes</i>							
Cottidae	<i>Myoxocephalus octodecemspinosus</i>	Longhorn sculpin	Chaboisseau à dix-huit épines	300	<a href="#">159520</a>	3292	L

Family	Scientific name	English name	French name	Species code	AphiaID	Num. records	Category
	<i>Myoxocephalus scorpius</i>	Shorthorn sculpin	Chaboisseau à épines courtes	301	<a href="#">127203</a>	131	LR
	<i>Myoxocephalus aeneus</i>	Grubby	Chaboisseau bronzé	303	<a href="#">159519</a>	40	LR
	<i>Triglops murrayi</i>	Moustache sculpin	Faux-trigle armé	304	<a href="#">127205</a>	1182	L
	<i>Artediiellus uncinatus</i>	Arctic hookear sculpin	Hameçon neigeux	306	<a href="#">127195</a>	306	I
Psychrolutidae	<i>Cottunculus microps</i>	Polar sculpin	Cotte polaire	307	<a href="#">127235</a>	29	LR
Cottidae	<i>Icelus spatula</i>	Spatulate sculpin	Icèle spatulée	314	<a href="#">127200</a>	40	LR
Hemitripteriidae	<i>Hemitripterus americanus</i>	Sea raven	Hémitriptère atlantique	320	<a href="#">159518</a>	2126	L
Agonidae	<i>Aspidophoroides monopterygius</i>	Alligatorfish	Poisson-alligator atlantique	340	<a href="#">159459</a>	1029	L
	<i>Ulcina olrikii</i>	Arctic alligatorfish	Poisson-alligator arctique	341	<a href="#">274356</a>	13	LR
	<i>Leptagonus decagonus</i>	Atlantic poacher	Agone atlantique	350	<a href="#">127191</a>	266	I
	<i>Agonidae</i>	Alligatorfishes	Poissons-alligator	351	<a href="#">125588</a>	43	LR
<i>Lophiiformes</i>	<i>Lophius americanus</i>	Monkfish	Baudroie d'Amérique	400	<a href="#">159184</a>	1970	L
<i>Gadiformes</i>	<i>Nezumia bairdii</i>	Marlin-spike grenadier	Grenadier du Grand Banc	410	<a href="#">183289</a>	529	I
	<i>Trachyrincus murrayi</i>	Roughnose grenadier	Grenadier-scie	412	<a href="#">126481</a>	18	LR
	<i>Coryphaenoides rupestris</i>	Roundnose grenadier	Grenadier de roche	414	<a href="#">158960</a>	17	LR
<i>Scorpaeniformes</i>	<i>Cyclopterus lumpus</i>	Lumpfish	Lompe	501	<a href="#">127214</a>	216	I



Family	Scientific name	English name	French name	Species code	AphiaID	Num. records	Category
Liparidae	<i>Eumicrotremus spinosus</i>	Atlantic spiny lumpsucker	Petite poule de mer atlantique	502	<a href="#">127217</a>	226	I
	<i>Liparis atlanticus</i>	Atlantic seasnail	Limace atlantique	503	<a href="#">159524</a>	34	LR
	<i>Liparis fabricii</i>	Gelatinous snailfish	Limace gélatineuse	505	<a href="#">127218</a>	27	LR
	<i>Liparis gibbus</i>	Variegated snailfish	Limace marbée	512	<a href="#">159526</a>	41	LR
	<i>Careproctus reinhardtii</i>	Sea tadpole	Petite limace de mer	520	<a href="#">127212</a>	18	LR
<i>Perciformes</i>							
Zoarcidae	<i>Lycenchelys verrillii</i>	Wolf eelpout	Lycode à tête longue	603	<a href="#">159258</a>	40	LR
<i>Anguilliformes</i>							
Nemichthyidae	<i>Nemichthys scolopaceus</i>	Slender snipe eel	Avocette ruban	604	<a href="#">126306</a>	28	LR
<i>Perciformes</i>							
Ammodytidae	<i>Ammodytes dubius</i>	Sand lance	Langon	610	<a href="#">151520</a>	1283	I
Zoarcidae	<i>Lycodes terraenovae</i>	Newfoundland eelpout	Lycode du Labrador	619	<a href="#">127117</a>	64	LR
	<i>Lycodes lavalaei</i>	Newfoundland eelpout	Lycode du Labrador	620	<a href="#">127107</a>	72	LR
Pholidae	<i>Pholis gunnellus</i>	Rock gunnel	Sigouine de roche	621	<a href="#">126996</a>	21	LR
Stichaeidae	<i>Lumpenus lampretaeformis</i>	Snakeblenny	Lompénie-serpent	622	<a href="#">154675</a>	423	I
	<i>Leptoclinus maculatus</i>	Daubed shanny	Lompénie tachetée	623	<a href="#">127072</a>	443	I
	<i>Ulvaria subbifurcata</i>	Radiated shanny	Ulvaire deux-lignes	625	<a href="#">159821</a>	145	LR
	<i>Eumesogrammus praecius</i>	Fourline snakeblenny	Quatre-lignes atlantique	626	<a href="#">159817</a>	40	LR
Cryptacanthodidae	<i>Cryptacanthodes maculatus</i>	Wrymouth	Terrassier tacheté	630	<a href="#">159675</a>	120	LR
Callionymidae	<i>Foetorepus agassizii</i>	Spotfin dragonet	Dragonnnet tacheté	637	<a href="#">276339</a>	20	LR

Family	Scientific name	English name	French name	Species code	AphiaID	Num. records	Category
Zoarcidae	<i>Zoarces americanus</i>	Ocean pout	Loquette d'Amérique	640	<a href="#">159267</a>	1478	L
	<i>Lycodes reticulatus</i>	Arctic eelpout	Lycode arctique	641	<a href="#">127112</a>	70	LR
	<i>Melanostigma atlanticum</i>	Atlantic soft pout	Molasse atlantique	646	<a href="#">127120</a>	43	LR
	<i>Lycodes vahlii</i>	Vahl's eelpout	Lycode à carreaux	647	<a href="#">127118</a>	565	I
Stromateidae	<i>Peprilus triacanthus</i>	Atlantic butterflyfish	Stromaté fossette	701	<a href="#">159828</a>	487	I
Zeiformes	<i>Zenopsis conchifer</i>	Silvery John dory	Saint Pierre argenté	704	<a href="#">127426</a>	39	LR
Aulopiformes	<i>Arctozenus risso</i>	White barracudina	Lussion blanc	712	<a href="#">126352</a>	196	LR
Belontiiformes	<i>Scomberesox saurus</i>	Atlantic saury	Balaou atlantique	720	<a href="#">126392</a>	37	LR
Stomiiformes	<i>Sternoptychidae</i>	Hatchetfishes	Haches d'argent	741	<a href="#">125603</a>	21	LR
Lophiiformes	<i>Dibranchus atlanticus</i>	Atlantic batfish	Mathe atlantique	742	<a href="#">126558</a>	18	LR
Pleuronectiformes	<i>Symphurus diomedeanus</i>	Spottedfin tonguefish	Langue fil noir	816	<a href="#">159358</a>	24	LR
Scorpaeniformes	<i>Artediiellus atlanticus</i>	Atlantic hookear sculpin	Hameçon atlantique	880	<a href="#">127193</a>	258	I
Elasmobranchii							
Rajiformes							
Rajidae	<i>Dipturus laevis</i>	Barndoor skate	Grande raie	200	<a href="#">158548</a>	246	I
	<i>Amblyraja radiata</i>	Thorny skate	Raie épineuse	201	<a href="#">105865</a>	3937	L
	<i>Malacoraja senta</i>	Smooth skate	Raie lisse	202	<a href="#">158554</a>	1773	L

Family	Scientific name	English name	French name	Species code	AphiaID	Num. records	Category
	<i>Leucoraja erinacea</i>	Little skate	Raie hérisson	203	<a href="#">158551</a>	712	I
	<i>Leucoraja ocellata</i>	Winter skate	Raie tachetée	204	<a href="#">158553</a>	1180	L
<i>Squaliformes</i>							
Squalidae	<i>Squalus acanthias</i>	Picked dogfish	Aiguillat commun	220	<a href="#">105923</a>	1985	L
Etmopteridae	<i>Centroscyllium fabricii</i>	Black dogfish	Aiguillat noir	221	<a href="#">105906</a>	31	LR
<b>Cephalopoda</b>							
Oegopsida							
Ommastrephidae	<i>Illex illecebrosus</i>	Northern shortfin squid	Encornet rouge nordique	4511	<a href="#">153087</a>	4836	L
<i>Myopsida</i>							
Loliginidae	<i>Doryteuthis pealeii</i>	Longfin inshore squid	Calmar totam	4512	<a href="#">574541</a>	96	LR
<b>Malacostraca</b>							
<i>Decapoda</i>							
Pandalidae	<i>Pandalus borealis</i>	Northern prawn	Crevette nordique	2211	<a href="#">107649</a>	718	S
Cancridae	<i>Cancer borealis</i>	Jonah crab	Tourteau jona	2511	<a href="#">158056</a>	1387	S
	<i>Cancer irroratus</i>	Atlantic rock crab	Tourteau poinçlos	2513	<a href="#">158057</a>	788	S
Oregoniidae	<i>Hyas coarctatus</i>	Arctic lyre crab	Crabe Hyas coarctatus	2521	<a href="#">107323</a>	711	S
Lithodidae	<i>Lithodes maja</i>	Atlantic king crab	Crabe épineux du nord	2523	<a href="#">107205</a>	531	S
Oregoniidae	<i>Chionoecetes opilio</i>	Queen crab	Crabe des neiges	2526	<a href="#">107315</a>	1546	S
Geryonidae	<i>Hyas araneus</i>	Great spider crab	Crabe lyre araignée	2527	<a href="#">107322</a>	625	S
	<i>Chaceon quinquedens</i>	Red deepsea crab	Crabe rouge	2532	<a href="#">158407</a>	33	SR
Nephropidae	<i>Homarus americanus</i>	American lobster	Homard américain	2550	<a href="#">156134</a>	1623	S

## **2.4 Analyses**

The Oracle relational database where all data are stored was accessible from the Bedford Institute of Oceanography in Dartmouth, Nova Scotia. Structured Query Language (SQL) is used to extract the data from the production server and to create the data products used in all subsequent analyses. Catch records classified as "valid" (i.e. a representative tow without damage to the net) are used in the current analyses. To make the available samples comparable, catch number and weight for each species was standardized for the distance towed.

All data processing and analyses were conducted using the R software (R Core Team 2020) using packages gstat (Pebesma 2004), PBSmapping (Schnute et al. 2019), RODBC (Ripley and Lapsley 2019), spatstat (Baddeley 2015), maptools (Bivand and Lewin-Koh 2020), rgeos (Bivand and Rundel 2020), classInt(Bivand 2020), RColorBrewer(Neuwirth 2014), MASS (Ripley et al. 2020), worms (Holstein 2018), and tidyverse (Wickham 2019). The present document is rendered as a Technical Report using the csasdown R package developed and maintained by Fisheries and Oceans Canada scientists (Anderson et al. In press).

### **2.4.1 Geographic distribution of catches**

Spatial interpolation of catch biomass (kg/tow) or abundance (number/tow) was done using a weighting inversely proportional to the distance, using function "idw" of the spatstat R package (Baddeley 2015).

### **2.4.2 Abundance and biomass indices**

For each species, stratified random estimates of catch abundance and biomass (Smith 1996) were computed for each year. Yearly estimates of the standard error were also computed.

### **2.4.3 Distribution indices**

For each Category L, I and S fish species, the minimum area required to account for 75% and 95% of the total biomass or abundance were computed (D75% and D95%). These measures of distributions were computed for each year by using the Lorenz curve of mean stratum-level catch estimates and the area of occupied strata (Swain and Sinclair 1994; Swain and Morin 1996).

### **2.4.4 Length frequencies**

The length frequency distribution of catch is tabulated for each seven-year period (1970-2009), and last ten-year period (2010-2020).

#### 2.4.5 Length-weight relationship and condition factor

The relationship between the weight and the length of fish was estimated using the following non-linear isometric relationship:

$$W = \alpha L^\beta$$

where  $W$  is the total weight (g),  $L$  is the length (cm), and,  $\alpha$  and  $\beta$  are the parameters to be estimated.

Average fish condition ( $C$ ) was computed as:

$$C = \frac{W}{\alpha L^\beta}$$

#### 2.4.6 Depth, temperature and salinity distribution of catches

For each category  $L$  species, We followed the methods developed by (Perry and Smith 1994) and generated cumulative frequency distributions of depth, temperature and salinity of survey catches.

#### 2.4.7 Density-dependent habitat selection

We followed the methods of (Myers and Stokes 1989) to evaluate how fish abundance in each stratum varied with overall temporal fluctuations of population abundance.

For each category  $L$  species, we fitted a model of the relationship between stratum-level density and overall abundance (the yearly stratified random estimate of abundance, defined above). To properly use the observations of zero catch while accounting for the logarithmic distribution of catch abundance, we implemented the model as a generalised linear using a log link and a Poisson error distribution:

$$Y_{h,i} = \alpha_h Y_i^{\beta_h}$$

where,  $y_{h,i}$  is the average abundance of stratum  $h$  in year  $i$ , and  $\alpha_{h,i}$  and  $\beta_{h,i}$  are the fitted parameters. The estimated parameter  $\beta_{h,i}$  is referred to as the “slope parameter” and indicates whether stratum-level density is positively ( $\beta_{h,i} \leq 0$ ), negatively ( $\beta_{h,i} \geq 0$ ) or negligibly ( $\beta_{h,i} \approx 0$ ) related to population abundance.

To estimate the suitability of each stratum, the median abundance observed during the years that are in the top 25% of yearly estimates is used. We combine the slope parameter estimates from the above model with the median abundance to identify strata that have consistently high abundance and whose local density is weakly related to fluctuation in population abundance ( $\beta_{h,i} \approx 0$ ). Preferred strata are identified for each category  $L$  species.

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